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Anthropocentric-based robotic and autonomous systems: assessment for new organisational options

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Anthropocentric-based robotic and autonomous systems: assessment for new organisational options [1]

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Abstract

Research activities at European level on the concept of new working environments offers considerable attention to the challenges of the increased competencies of people working together with automated technologies. Since the decade of 1980 the development of approaches for the humanization of work organization, and for the development of participative organizational options induced to new proposals related to the development of complex and integrated automated systems. From such parallel conceptual development emerged the concept of "anthropocentric robotic systems" and quickly it covered also other fields of automation. More recently, the debate also covers issues related to working perception of people dealing with autonomous systems (e.g. Autonomous robotics) in tasks related to production planning, to programming and to process control. In fact, today one can understand the wider use of the anthropocentrism concept of production architectures, when understanding the new quality of these systems. In this chapter the author analyses the evolution of these issues related to governance of ICT applied to manufacturing and industrial services in research programmes strengthening very much the 'classical' concept of anthropocentric-based systems. It is emerging a new value of the intuitive capacities and human knowledge in the optimization and flexibilization of the manufacturing processes. While this would be a pre-condition to understand the human-robot communication needs, there is also a need to take into consideration the qualitative variables in the definition and design of robotic systems, jobs and production systems.

Keywords: working environment; automation; work organization; Autonomous robotics; participative options; governance; human-robot communication

JEL codes: J81; L6; M11; O33

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Introduction

There are considerable research activities at European level on the concept of new working environments. These activities encompass the challenges of the increased competencies of people working together with automated technologies, and especially with robots. In fact, 344 thousand industrial robots were installed in European factories by the end of 2008. It represents a huge 'population' of machines that had its strong "demographic" increase in the 1990 decade, and still is been used intensively in manufacturing industry. One may surely state, that this sector is the one where most automated systems and robotics have been applied. Many application fields, within the debate on robots, still are not realised in industry, or not use in larger extend in the service sector.

This 'population' of industrial robots is used mostly for handling operations, or for welding and dispensing, but also for processing and for assembling and disassembling[2]. According to the European Platform of Robotics, one can consider different type of robots: industrial robots (for working environments as 'workers', 'co-workers' or for logistics), professional service robots (all applications), domestic service robots (co-workers, logistics and surveillance robots), security robots (the same as for domestic service, plus exploration and inspection), and even space robots (the same for industrial robots, plus exploration and inspection) [3].

The increase of industrial robots took part in the last decades at the same time when the work organization in the manufacturing industry has been under strong restructuring process. In several sectors (automotive, metal, electronics etc.) such restructuring has used the introduction of microelectronics in the labor process to improve the productivity and flexibility. In some case it had also used the industrial robots as one of the main technologies to support the renovation or upgrading of value chain. This modernization implied a new mode in terms of qualification needs and – above all – new organizational alternatives. In this chapter we will discuss the evolution of the technology options for new market conditions within the strategic choices governed by the management models in the manufacturing industry. These choices can be done among the more technocentric approaches (supported on Tayloristic "one best way" model) or the anthropocentric ones based on idea that a more participative and learning organization is the one that can cope with flexibility and complexity of technical systems.

[2] An important task that had become a recent increase because of the development of the recycling industry.
[3] We will not consider for propose of this chapter the "edutainment" (education and/or entertainment) robots, although some autonomous systems have been experienced with such application of service robots (e.g. "robocup").

Research findings on working conditions and automation

Already in the 1970 decade, the International Labour Office (ILO) was the main institution that published several studies about the relation between workers and technology, specially, ICT and embedded micro-processors in the working environment (most were mentioned by other sociological research publications, like Braverman 1974; Bell 1976; Kern & Schumann 1984; Piore & Sabel 1984; Bessant 1989), and came to the result that the increase of automated system have created new types of problems. Without any doubt, such new technologies increased the pace of work and the intensitivity of human tasks, but in other cases it gave floor to the implementation of new forms of work organization and increased participation in the decision making by workers. In both cases, most of the problems definitely seemed related with new needs for the improvement of working conditions.

On the other side automated technologies offereda new opportunity to include the need for expertise from the workers to better balance the production lines and also improved the quality control of what? At that time (decade of 1970 and early 1980) some studies were developed on automated transfer systems in the manufacturing industry, the development of numerical controlled machine tools, and the beginning of the introduction of micro-processors in the office work (Brandt, 1992; Brödner, 1990; Davis and Wacker, 1982, Hertog and Schroder, 1989). They gave a new insight on the importance of social aspects related with the introduction of ICT at the workplace. Tese studies raised the attention to new aspects related with the work organization, and with knowledge needs to deal with such technologies (specific training, basic competences, informal knowledge).

Besides ILO, in this decade, the European Foundation for the Improvement of Living and Working Conditions [4] was founded as a European Commission unit to analyse issues related to the emergence of new forms of work organization, and for the analysis of working condition. It has supported and published several sectoral studies held during these first years of the decade of 1980. The European Foundation also started in 1992 the organization and publication of European surveys on work environment (European Foundation, 1992). Later, during the years 1993-98, it carried out a major programme of research dealing with the nature and extent of the direct participation that is at the heart of new forms of work organization, known as EPOC (Employee direct Participation in Organisational Change) programme. Some years later (in 2001), the European Foundation set up the European Monitoring Centre on Change (EMCC) which is an information resource established to promote an understanding of how to anticipate and manage change. This observatory had the full support of the European Parliament, the European Commission and the social

[4] It was one of the first units to be established to work in specialised areas of EU policy. Specifically, it was set up by the European Council in 1975, to contribute to the planning and design of better living and working conditions in Europe.

partners. These activities were focused on the organizational changes and anticipation of work environment changes. Some studies on automation and robotics were held but no case studies were developed. Mostly they were integrated in more general reports on national or sectoral restructuring and modernisation processes. The aim of those studies was to understand the sector restructuring in Europe. Because of that some comments, observations and data collection was made relating to examples of automation development in some member states, and sectors. Some of those studies also included analysis about robotics implementation in manufacturing (automobile, electronics, metal engineering, etc.). Just few public discussions were held specifically on those topics of technology change and automation implications. And those held were especially focused on the role of social partners in the restructuring process. No specific results can be retrieved on the issue of robotics and/or autonomous systems used in the productive sectors.

On another institutional basis, the European Commission coordinated also research activities during the 1980s in the field of Anthropocentric Robotic Systems that influenced the ESPRIT-European Strategic Programme of Research in Information Technologies programme during several decades, and a wide group of European social scientist. It was a field that encompassed the wider topic of human-centred systems, or advanced production systems and participative organisation, but more focused on robotics. The attention to such field does not arised only after 2000 with the so-called "Lisbon Strategy" but from decades earlier, for example, with the activities at the Forecasting and Assessment in Science and Technologies (FAST) unit of DG Research. This unit paved the ground for new networks and research projects (Brandt 1992; CEC-FAST 1987; FAST 1989; Hertog & Schroder 1989; Jones, Kovács & Moniz 1988; Kidd 1992). Such projects and research networks contributed to the knowledge towards the different technological design options (agile manufacturing, balanced automation systems, virtual enterprises, production networks, etc.). And, although many studies were published on social aspects of automation, these underlined the dimensions of technological design alternatives.

Usually, it was assumed that robotic technology was "given" and developed by advanced engineering centres using the most advanced concepts and state-of-the-art knowledge of technology. Only on the base of these preconditions it was possible to understand the results of implementation, the impacts or the implications for employment, new qualification needs for the workers or the whole job design. Thus, after those (awareness) studies it was possible to understand how important the design of technology became, and how far it can be driven by political, ethical or social aspects. Alt least, it also was understood that different industrial robots manufacturers develop their products according to different organizational principles or approaches. For example, in the D. Brandt report on anthropocentric production systems experiences (Brandt 1990) are mentioned experiences of machine tool manufacturers that developed their systems to facilitate the operators' control of production process. More recently, in the SME Robot project (see pages …) a generic graphic human-machine interface was developed where the processes are combined and inserts process parameters according to user description. That means that no manual configuration effort is required or no knowledge of device interface is required. It can use the graphical layout to generate a real robot controller system with assistance to help the user to correctly set-up the robot cell. Comau, KUKA, ABB and Reis industrial robot manufacturers were the companies involved in such projects. This means they can also profit from the results. But also this means that the research outcomes can be an important tool for an organizational alternative where robot operators can participate in the production control process.

In this sense the FAST unit on 'forecasting and assessment on science and technology' assumed as research field the "anthropocentric production systems", and paved the ground for new networks and research project. In particular, that happened within some of the first ESPRIT projects.[5] These projects were based on the assumption of the feasibility of design and implementation of flexible manufacturing systems (FMS) and computer integrated manufacturing (CIM) systems that use human operators as key elements of such automation strategies (cf. Brandt 1992; Brödner 1990; Kidd 1992). Key elements because they were designed not to exclude the human participation on operative tasks, and also on planning and programming [6]. On the contrary, these strategies intended to use and to integrate human operators' skills and competences in order to improve the decision processes of workers and robot operators in shop floor manufacturing environment. Either in the product design phase, or during the manufacture process. In this case, that automation strategy of increased human involvement in the decision process was done where automated machinery need to be programmed. And especially when there are higher risk probabilities in terms of quality assessment and control in complex manufacturing environments.

As mentioned by Rauner and Ruth "the method of user participation is based on the assumption that the involvement of the users will cause better systems, because on the one hand it better meets the needs and skills of the working people, on the other hand only the users at shop floor level have the knowledge of the 'real' production processes which of course must be included in the technical design process. Evidently users must be involved from the beginning and during the whole

[5] Especially the ESPRIT 1217/1199 project on "Human-centred CIM Systems" that was pioneering the organised research at the EC level on these issues). The project ESPRIT 534 (Development of a Flexible Automated Assembly Cell and Associated Human Factor Study), also was focused on the same topics. More information on this can be also read at Nichols & Jones 1994; Laessoe & Rassmussen 1989; Burns 2000.

[6] Some companies were announcing about the future "unmanned factory", about the total automated units that did not need or use human work operation. That would be the highest achievement in terms of competitivity. Such naïve approach produced strong impacts at the management structures.

participative process" (Rauner and Ruth, 1991, p. 21). This is still valid in the present days.

Since the European 5th Framework Programme of R&D, that is to say only from 1999 onwards, new projects have been supported to develop some specific concepts and ideas, like "participatory technology assessment", "work process knowledge", learning organisations, collaborative knowledge modelling, or "virtual organisations", among others. That means such research projects could use new concepts of management sciences and integrate the major experiences and results from the work organization restructuring models (semi-autonomous working groups, production islands, "U" assembly lines, autonomous cells, multitasking working places, etc.). The discussion over international experiences of new forms of work organization in the manufacturing sector (especially in the automobile, chemical and electronic companies) were progressively integrated into new research programs on ICT engineering, or in the social sciences agenda.

These new concepts were rooted into the organizational approach of socio-technical design based on the Emery, Trist or Gustavsen studies in the decade of 1960. The Tavistock Institute research findings from the 1950 decade were being used by the new organizational research approaches almost up to four decades later. Under that European research framework programme, some projects were dealing with flexible work practices based on principles such as decentralization, multi-competences, vertical and horizontal integration of tasks, participation and co-operation, that were already features of human-centred approaches to automation systems. This was also the case for TSER [7] program projects like SOWING [8].

This was also the case for the engineering research on automation and development of manufacturing integration through ICT components and design of new productions flows that could improve the working conditions of the workers and on the same time to improve the productivity levels.

When taken these aspects into account it is necessary to analyse, and to assess these integrated socio-technical system approaches. Several were the experiences to develop such integration, specially the new systemic relation between the organization, the technical system and the social and economical environment. Some cases have been mentioned by Clegg & Corbett 1987, Brandt 1992, or Rauner & Ruth 1991, but also by authors from the socio-technical approach, like Child or Mumford (cf. Castillo 1988), or others more disperse from the sociological and management sciences literature.

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[7] TSER stands for Targeted Socio-Economical Research and was the sub-programme of R&D financial support for social sciences research projects in the 4th and 5th European Framework Programme.

[8] http://www.uta.fi/laitokset/tyoelama/sowing/sowing.html

These experiences were in the same stream of the research on alternative organization of work. They followed the main findings from social research in Europe, butalso in the US or in Japan [9], where they pointed to the emergence of network-based information economy with an intense restructuring process on the level of manufacturing organizations. That led to new technological needs, and also to new social and economic demands. Quality, productivity, flexibility, uncertainty, complexity, efficiency were concepts that seem contradictory, but they could be tackled integrating simultaneously within a social and a technological dimension. Some of those experiences at the manufacturing level were related to the design of new robotics cells and integration of those cells into highly sophisticated manufacturing systems that still could use the participation of human decision skills in production planning, programming and control. At least there was some effort to integrate human participation into technological advance.

Nowadays one can recognize that the demands for the improvement of the working circumstances have been cooled down by competition limits and by an intense growing of work pressure and employment instability. With such processes of degradation of work conditions, also the push for a technological development of social design of autonomous technical systems seems in a stabilized process. It has been only focused on intelligent ambiance and machine-machine communication systems [10]. Some research is also supporting the inclusion of human tacit knowledge into artificial reasoning with more powerful programming tools. But this human-machine interfacing is basically instrumental, and not a social or political dimension of the technical design option.

Experiences with anthropocentric strategies for automation and robot systems in manufacturing

Most of the experiences on anthropocentric strategies for automation in manufacturing had their floor in Europe. As Rauner and Ruth underlines, that “the implicit ‘Eurocentric’ orientation (…) finds expression, for example, in the welfare state premises included that do not exist to the same degree in the US and Japen” (Rauner & Ruth, 1991: p. 7). They followed the industrial approaches in Japan to participatory design of organizations and implementation of quality control policies in sectors where was needed a major involvement of human operators. The most

[9] The CAPIRN project (Culture and Production International Research Network) developed the concept of “industrial culture” from case studies from the major industrialized countries, and their outcomes were also an input to the FAST program on anthropocentric production systems (cf. Rauner & Ruth 1991),

[10] Cf. Ribeiro and Barata 2006 or Moniz 2007.

studied ones were held in Sweden (Volvo experiences) and Denmark (B&O, MAN B&W Diesel and other companies in metal and electronics sectors), all involving strongly the social partners in the restructuring process. But other studies were held in Germany and UK (all in wider ranges of sectors [11]), and some others in other industrialized countries like Italy (most in Emilia Romagna, either related with automotive or electronics, and in other Northern Italy regions with garment and textile sector), Spain (in the Mondragón region) or France (in several different sectors and regions) [12]. Here the main issue for its application was to cope with problem solving in productivity and flexibility of production systems. When compared to the same type of organization in the US and in Japan, the European companies were much left behind in terms of productivity capacities. The fact that they could not achieve the flexibility capacities of Japanese and US firms in the same sectors that mean that the results in terms of productivity were also poor.

In Japan the participative strategies were developed and applied since late 70s, and in the US the lean production methods were applied in late 1980s in the manufacturing sectors. In Europe, only the Scandinavian experiences are based on these technical systems (ILO, 1984). As it was described above, robotic systems in manufacturing has been considered (in the decade of 1980 by ILO, by OECD or the Vienna Centre) as a technology responsible for wealth and higher standards of living in Europe, not only due to higher levels of attained productivity, but also to the contribution to improve working conditions. That was, at least, the main argument for the increased acceptance of the introduction of robotic systems at the workplace. And manufacturing industry was without doubt the sector where most of robots and automated systems were applied and developed.

Basically, experiences like the Volvo Kalmar case, the SAAB, or the MAN B&D Diesel, or many others from Norway and Finland were related to the implementation of new forms of work organization. But in almost all of the manufacturing industry cases, the implementation of robots and flexible manufacturing systems was done smoothly with the participation of work council and the workers directly involved in the restructuring processes

The Scandinavian socio-technical systems involve self-managed teamwork and work enrichment by multi-skilling. Learning organisations are characterised by strong individual and collective learning dynamics in the workplace, notably with regard to problem-solving activities related to unforeseen events such as dysfunctions in production and with regard to innovation processes. These organisations need high

[11] Brandt (1992) mentions cases of Thyssen and Hoesch (steel, Germany), Keller, Felten&Guillaume and Lubos&Bayer (metal engineering, Germany), Rolls-Royce and Westland Helicopters (aircraft, UK), Lucas Engineering (electronics, UK).

[12] It is worth to consult most of the references presented in this chapter. In particular, Clegg & Corbett 1987; Castillo 1988; Warner, Wobbe & Brödner 1990; Rauner & Ruth 1991; Brandt 1992; Kidd 1992; Lehner 1992; Freyssenet 1995; Durand, Stewart & Castillo 1998, or even Valeyre 2009.

levels of autonomy, initiative and communication at work on the part of employees and attach great importance to autonomous teams and project teams. Based on collective reflexive returns to tasks and events and assigning a larger intelligibility to work (Freyssenet 1995), they clearly break with Taylorist principles (cf. Valeyre et al. 2009).

Jürgens, Malsch and Dohse (1993) argued that the high average levels of qualified labour in the automotive and sectors or in companies that introduced robotic systems, was an argument to develop the experiences with work organization and to design the robotic systems in order to integrate the cooperation of human tasks.

The technical and economical advantages that follow such experiences are associated to improved quality (less rejects and flaws) and increased responsiveness. However, it can also induce shorter throughput times, lower indirect costs and an easier planning and control of production processes. The development of organizational innovations with flexible automation systems imply simplified material flows than with conventional organizational models, and also implies smaller production areas and swifter response to quantitative and qualitative changes in demand. Less breakdowns and increased capacity for innovation and continuous (productivity, quality) improvement, are also features of those systems.

These experiences have shown that even from the social and human point of view the benefits of implementation robotic systems can be considered as an increasing quality of working life, a higher job satisfaction through meaningful rewarding tasks, and an higher degree of motivation and involvement. It implies also a greater personal flexibility and adaptation, and an improved ability, creativity and skills of the shop floor personnel, which requires higher levels of qualification.

An enriched direct interpersonal communication and social relations, increased collective and co-operative will, and a greater capacity for collective learning of new practices are also human and social benefits of those above mentioned systems that articulate organizational innovation and flexible technology applied to production. Thus, in the very beginning of the scientific debates based on research programmes about robotic systems had a positive impact on the emergence of knowledge about the organizational aspects related to the implementation of advanced automated and integrated systems. Such knowledge made possible further research on organizational conditions to provide a better usage of robotic systems and advanced integrated automation. Several experiences were supported and reported through European projects to study these new forms of work organization with automated systems.

In the next item we will focus more on the European research frameworks and the projects on robotics that included dimensions related to user-interfaces, to new hardware configurations to face user needs, or to new software strategies centred on human (normally, shop floor operator competences, not engineer or technician competences).

The research frameworks in Europe and robotics

In fact, since the decade of 1990, automation and robotics were at the stake of large European research projects. Several of these projects developed anthropocentric automation approaches. Most of them included inter-disciplinary research teams (engineers, sociologists, management scientists, computer scientists and social psychologists) and provided very interesting scientific literature on major issues related with the challenges that manufacturing industry was facing Europe by the end of the 20th century. With the emergence of new innovation problems (globalization, network and virtual enterprises, technical integration) the focus was becoming more technical-oriented. Although, one can find in every European framework programme of RTD a *continuum* of projects that are dealing with the human-centred configuration of automated systems. New approaches were tested, new more complex experiences took place with the support of those programs, and the debate could continue. From the beginning of the new century, the Lisbon strategy offered also new topics to be responded, and the research institutions together with industry firms tried to cope with those new issues of the framework programmes. In the next lines we report on that evolution and on project examples under each of those European programmes.

Since the 2nd Framework Programme, some ESPRIT and BRITE-Basic Research in Industrial Technologies for Europe projects can be considered as reference frameworks for the collaborative research between the Computer Sciences, Quality and Production Engineering, and Sociology. It was under these projects that social sciences could have major applied research in manufacturing environments [13]. Later, in the ESPRIT 4 programme [14] the research activity on robotics was focusing in four domains: a) "Integration in Manufacturing" (IiM), b) "High Performance Computing and Networking" (HPCN), c) "Technologies for Components and Subsystems" (TCS), and d) "Long Term Research" (LTR). But these domains of 4th Framework

[13] In particular projects with special references to Social Sciences can be mentioned, as the project ESPRIT 1199/1217 “Human-Centered CIM Systems”, or the project ESPRIT 5564 “Integrated Design and Evaluation of Assembly Lines within CIM”, or the BRITE projects 1381 (on interactive knowledge based shop floor control systems), 3302 (on Decision Support Systems) or 3345 (on flexible production groups), or even the ESPRIT exploratory action 5603 on “Joint Technical and Organizational Design of CIM systems for SME’s”. Some of these issues were already discussed in a previous article (Moniz 2007) on the importance of these projects for the emergence of such techno-organisational concepts.

[14] This European strategic programme was held from 1994 until 1998 by the European Commission involving all the member states.

Programme included also the issue “user-centred development” on robotics. Such User-Centred Development issue included the integration of user-centred approaches into methods and tools supporting the design and development of systems. Also could be defined through the concept of "Usability Support Environments" which means that it should support user’s involvement and feed back through techniques and tools such as early story-board prototyping, simulations to evaluate user reaction, user profile analysis, and so forth.

This new European programme was focusing much more the ICT research towards the usability principles and the human-machine interfaces improvement. However, the organizational issues related to job design in complex and integrated systems was not anymore a research topic. The IiM domain should be the one where such topics should be developed under R&D projects.

An overview of Robotics Technologies in RTD Programmes of the European Community under the 4th Framework Programme was published by the European Commission by Skordas and Robrock, and there they specify that the domain IiM also focused on robotics projects and preparatory support and transfer activities that are specific to the manufacturing domain. These are related to the theme of ‘Intelligent Production Systems’ and Equipment comprising some research tasks (what is that?). Among those it seems worth to mention the development of enhanced man-machines IT interfaces for control systems and shop-floor control (mostly in manufacturing industry), and the development of distributed computing environments supporting novel control and decision support methods, for control of manufacturing processes. IT became a clear dominant technical role within the technical systems and specifically in the last decades the European RTD Programmes in the field of autonomous systems (including robotics) were supporting almost exclusively interfaces systems. But also research tasks were taken under that Integration in Manufacturing domain, as the development in IT components and subsystems and embedded micro-devices, and their integration, for open, intelligent, autonomous mechatronic systems. This implies another field that also requires possible user-centred strategies is the integration of real-time quality and performance monitoring functions in flexible manufacturing systems. But no research projects were supported in these fields.

One of the IiM project clusters was the “Intelligent Equipment and control” that comprises a total number of 10 ESPRIT projects in the areas of enhanced man machine interfaces for shop-floor control, computing environments for control of manufacturing processes and IT components and subsystems and embedded micro-devices for robotics and mechatronic systems. But again, no projects appeared to develop further knowledge on the relation of organization and technology, beyond these areas of human-machine interfaces or control systems.

The sectors of robotics manufacturing and machine communications could be represented through the projects AMIRA (EP22646) and RACKS (EP20468) that were the single projects focusing on aspects related to users of this automation technology. The objective of AMIRA was the development of the next generation of advanced man-machine interfaces. Also it was intended to support tools to end-users of robot manipulators for efficient application of robot systems and robotised workcells. The RACKS project was concerned with the situation in the field bus based market and tackles the bottleneck of heavy dependence of manufacturing systems towards the underlying technology used of communication networks. It had also the aim to develop standard user-level common interfaces rendering application programs compatible with a wide range of system architectures. In another ESPRIT field, the Industrial and Materials Technologies Programme (IMT) of the 4th Framework Programme replaced the former BRITE-EURAM, but continued to include a research agenda in the robotics field, covering several topics: intelligent assembly, mechatronics, and micro-system technologies, new quality oriented intelligent and flexible production systems, tele-operated multifunctional robotic systems, joining, inspection and repairing systems incorporating mechatronics, micro-systems, sensors and actuators for real time adaptive control and research on new automatic control and systems theory concepts. Also in this production technologies are of IMT it included the field of "human and organisational factors in production systems", but no projects reflecting such field was supported.

In April 1997 the European Commission published its Green Paper on "Partnership for a New Organisation of Work" (European Commission 1997). As Brödner and Latniak mention, "it did not really produce a signal for departures to new frontiers; it was rather turned down instead during public debates that followed. In the time after, a Communication Paper entitled 'Modernising the Organisation of Work – a Positive Approach to Change' (European Commission 1998) was issued in November 1998, and in March 1999 the European Work Organisation Network (EWON) has been established. These initiatives signed the weight the Commission assigned to the theme. Yet, their impact on the further development of new forms of work organisation has been rather low so far, although the Network appears to be necessary and helpful for improving the knowledge base across the member states, for exchanging experiences, and for raising public awareness for work organisation issues" (Brödner and Latniak, 2002, p. 7). In fact, we can find two reasons for this contradictory situation:

a) The European Green Paper is published by the end of the 1990 decade when the expectations on the organizational innovation reach the highest level. Many publications and experiences have shown that the participative and learning organizations could increase the productivity and product quality where the technological requisites have shown complexity and high modular integration;

b) The last decade (from early 2000) could be characterized by an intensification of labour in a process of increased segmentation of the value chain at a global level. This socio-economical trend pressured technological innovation into a decrease of costs and standardization of production processes.

Such contradictory trends have shown that it could be possible to increase production levels with a decrease of labour costs, with higher levels of control and flexibilisation. That implied a continuous investment on automation with more complex human-machine interfacing for a more reliable manufacturing control and management process. In the European 5th Framework Programme the involvement of larger companies in larger projects was envisaged, and new technological needs were under test. The programme IST (Information Society Technologies [15]) was again the most financially supported programme among all European RTD activities and had a specific topic on robotics: Beyond Robotics. The conclusions from Robotics Working Group Meeting 2002 of the IST programme reflected the main problems to be found in the technology field of robotics until the last years, like the following[16]:

- Interaction with robotic systems is extremely important as system only will be considered as "good" as their interface with the user.
- Today simple brain interfaces have started to emerge.
- Today (simple) multi-modal interfaces do exist for interaction with robots. Interfaces are either highly constrained, non-robust and/or require significant training.
- This call for significant advances in both, sensory perception, multi-modal interaction, methods for extended dialogue behaviours and integration of "physical behaviour" with the more traditional interaction modalities.
- A significant problem in design of robotic systems has been the lack of flexible and robust perception system that allows the system to operate in unconstrained environments.
- There is thus a need for careful consideration of the fusion of sensory perception beyond traditional semantic/Bayesian methods.

Again the topics related with the human user were based on "interface with the user", or "brain interfaces", training needs, "extended dialogue behaviours". But a concept

[15] It was not anymore called as ESPRIT programme.
[16] Cf. ftp://ftp.cordis.europa.eu/pub/ist/docs/fet/fetro-28.pdf.

about job design for operators of such systems was still missing. All efforts were based on the software and hardware aspects of robotics, but none on the integration robotic systems in “real life” environments in manufacture industry. Such topics revealed also the necessary developments of this technology. In fact, in recent years, the “usability” of robotic systems and the interface with their operators became a central issue for the research and the development of most used robotic technology, but the stress was put on software dimensions. The so called “brain interfaces” are recognized to be still in an early phase of the concept development. But other interfaces have been the main research topic in the recent years. Especially when related to distributed computing and large integration of sensors. Examples from the Karlsruhe experiences on autonomous robotics show us the evidence of such trends.

Later, at 6th Framework Programme (FP6) was approved the Robotics Platform (http://www.robotics-platform.eu/cms/index.php) as one of the European Technology Platforms-ETP supported. This European Robotics Technology Platform (EUROP) was founded in 2005, but in fact its roots go back to October 2004, when leading European robotics organisations started to formulate the need for a consolidated approach to European robotics. As the other ETP, the platform EUROP is an industry-driven framework for the main stakeholders in robotics to strengthen Europe’s competitiveness in robotic R&D, as well as global markets, and announced that it should contribute to improve quality of life.

In this European RTD programme the project that we can mention is the SMErobot (http://www.smerobot.org/). In this project there was an intention to empower the supply chain of robot automation by focusing on the needs and culture of SME manufacturing with regard to planning, operation and maintenance. That could be developed through a robot development capable of understanding human-like instructions (by voice, gesture, graphics), to increase the safety and productive human awareness in a shared space with robots (using cooperative principles, and not using protection fences). It is clear that in future robot instruction schemes it will be required the use of intuitive, multimodal interfaces and preferably human communication channels, such as speech and gestures. A strong effort has been made in this field for the last twenty years. Identification and localization of work pieces, automatic generation or adaptation of programs and process parameters are also required for minimizing programming efforts. In this project was concluded that the absence of highly skilled robotic programmers meant that relatively easy tasks take an average of 40 hours of programming for the average SME. The aim would be that robot programming should be as simple as telling a colleague to perform a certain task. That was also an aim of the first anthropocentric robot systems. The SMErobot project provided guidelines for anyone developing interfaces for industrial robots as how to design multi-modal interfaces based on voice, gesture or manual guidance for natural and intuitive human-robot interaction. That was the main objective to overcome the mentioned limits in the development of such systems to be applied to manufacturing companies, and especially to SME. It is a coordination of several

European activities that understand the usage of these autonomous systems much more than only IT programming systems that try to establish simplistic forms of reasoning to be easily understood by humans. The aims behind this research and development programme are grounded on artificial intelligence concepts and tools that can be articulated with social needs and competences requirements at the SME level.

Another project (PHRIENDS) was financed under this same framework programme and is about developing key components of the next generation of robots, including industrial robots and assist devices (http://www.phriends.eu/project.htm). This includes robots for the non-industrial applications market (service, health-care, and entertainment), and they were designed to share the environment and to physically interact with people. Such machines have – under this European project – to meet strict safety standards. The project faced new challenges to the design of all components of the robot, including mechanics, control, planning algorithms and supervision systems. It was envisaged an integrated approach to the co-design of robots for safe physical interaction with humans. That means to design robots that are intrinsically safe, and control them to deliver performance. Also financed under the FP6 was PACO-PLUS project (http://www.paco-plus.org/). This project brought together an interdisciplinary research team to design and build cognitive robots capable of developing perceptual, behavioural and cognitive categories that can be used, communicated and shared with other humans and artificial agents. This European project is undertaking the development of an integrated robotic system with humanoid traits to support interaction with people, in other words, to build a complex anthropomorphic robot. The researchers mention that "anthropomorphism is desirable because it makes interaction easier and also supports the transfer of ideas from psychology and neuroscience to robotics" (project webpage), although this idea is not proved or based in any evidence.

The ETHICBOTS is a project with some links to social sciences that aimed at identifying techno-ethical case-studies on the basis of a state-of-the-art survey in human-machine integration based on Robotics, Bionics, and AI for IA. This project is trying to identify and analyze techno-ethical issues concerning these forms of human-machine integration by reference to case-studies analysis. Will also establish a techno-ethically aware community of researchers, by promoting workshops, dissemination, training activities, and the construction of an internet knowledge-base and generate inputs to EU for techno-ethical monitoring, warning, and opinion generation. It was not clear if social scientists were participating directly in the project integrated in research teams with engineers and computer scientists.

Finally, at FP7 the euRobotics - Coordination Action for Robotics in Europe consortium covers the complete robotics picture including industry, service (both professional and domestic), security and space with the following aims: a) to develop a Strategic Research Agenda in Europe; b) address the broader impact of Advanced Robotics on society assessing the legal, social and ethical issues surrounding the introduction of Advanced Robots that directly interact with their users in everyday human environments. It will also assess the educational issues. It includes key players from both the industrially driven EUROP network and the academic network EURON. This Framework Programme is still running and new projects can tackle aspects that were previously pointed as needed to go deeper in the research. The technology assessment of these new systems can reach now a new standard level and integrate new tools for following up the project outcomes and to define new fields for further research. It is still too soon to evaluate those outcomes.

And under the FP7 the EU Project LIREC (LIving with Robots and IntEractive Companions)[17] seeks to establish a multi-faceted theory of artificial long-term companions. Is also an aim to embody this theory in robust and innovative robotics and in technologies of autonomous systems. It is also intended to experimentally verify both the theory and technology in real social environments, and to address social, psychological and cognitive foundations and consequences of such technological artifacts entering our daily lives.

HUMOUR is an EU-funded research project (http://www.humourproject.eu/) at the FP7 which aims at investigating and developing efficient robot strategies to facilitate the acquisition of motor skills. It tries to develop robot agents based on an advanced understanding of human euro-motor control, its development and skill acquisitioin. It aims also to extend the domain of Brain Computer Interface (BCI) technologies to the fields of motor learning and neuro-motor rehabilitation. Based also in the human-robot communication process, the CommRob project (http://www.commrob.eu/) has an underlying assumption concerning the robot’s interaction design that it should be based on principles of human-human communication in order to provide an interface that is intuitive and easy to use. The development of the communication platform envisioned in this project also provides another research challenge related to the dialogue design, namely that dialogue models should be generic and reusable. The research was oriented to design dialogue models based on established principles for human-machine interaction and ensuring that these models are thoroughly evaluated in realistic usage situations.

As one can understand, these projects were focusing along the last years several concepts associated to anthropocentric approaches, although sometimes in a very limited way. The examples of those concepts are the following:

a) design intrinsically safe robots, and control them to deliver performance (Phriends project)

[17] More information can be found at http://www.lirec.org/.

b) integrated robotic system with humanoid traits to support interaction with people (Paco-Plus project)

c) techno-ethical issues concerning these forms of human-machine integration (Ethicbots project)

d) innovative robotics and autonomous systems technologies for human interaction (Lirec project)

e) development
of robot agents based on an advanced understanding of human neuro-
motor control (Humour project)

f) intuitive robot's interaction design based on principles of human-human communication (CommRob project)

These were some few projects among a large database of European projects on robotics and autonomous systems [18]. It is possible to retrieve the projects that are dealing with social, human, ethical or legal aspects. The result is only these above mentioned projects where one can have a stronger impression on the research concepts that are been supported within the most important (in terms of financial resources) RTD programme for robotics research and information society technologies in general [19].

Principles of anthropocentrism on robotics

The concept to adopt anthropocentric approaches on robotics is very much related to the need of improving the work environment, and to increase the reliability of work procedures in complex and integrated systems. It is agreed for many years that a better work environment is not merely a physical environment (noise, light, repetitive tasks, etc.). It must include – always – the psychological and social dimensions. These are mostly related with the options for work organization models. When an "intelligent" equipment is introduced to mediate the work relation between people and the material to be transformed, this means that particular care must be given to that equipment, to that technology, to that "intelligence". For such reasons it can be concluded that an approach only based on interfaces improvements is very limited. Social, psychological, ethical dimensions need a veryadvanced research on robotic

[18] The information can be collected at the European Cordis database (http://cordis.europa.eu/).
[19] In reality, after the ESPRIT designation, the European Commission named this kind of research field the name "Information Society Technologies" or IST.

systems, especially when they are supposed to be integrated as “co-workers” in a manufacturing environment.

In this sense Rauner and Ruth present also an interesting definition: “the concept of anthropocentric production refers to healthy and qualified work, various cooperation and communication options, a maximum of scope for action and shaping on the part of employees (minimization of restrictiveness), technology that is shaped so as to be complementary to human abilities and development potential as well as social and ecological utility of the produced goods (Goods and not Bads)” (Rauner & Ruth 1991: p. 3). In fact, the concept of anthropocentrism is strongly related with the dimension of working conditions and physical and mental environments.

In the recent decades, the improvement of working conditions has been translated from research results and public debate also to the European legislation. In 1989 the Community Charter of the Fundamental Social Rights of Workers [20] stated that “The completion of the internal market must lead to an improvement in the living and working conditions of workers in the European Community. This process must result from an approximation of these conditions while the improvement is being maintained, as regards in particular the duration and organization of working time and forms of employment other than open-ended contracts, such as fixed-term contracts, part-time working, temporary and seasonal work”, and also that “Every worker must enjoy satisfactory health and safety conditions in his working environment. Appropriate measures must be taken in order to achieve further harmonization of conditions in this area while maintaining the improvements made”. Such movement for the improvement of working conditions in the manufacturing industries was a basis for the development of anthropocentric experiences with the implementation robotic cells or, in general, with the implementation of Flexible Manufacturing Systems. The basic components of an anthropocentric robotic system can be defined by the following elements:

- Flexible automation, supporting human work and decision making. It can be considered just a political strategy, but it has clear productivity consequences, as the next elements can demonstrate.
- A decentralized organization of work, with flat hierarchies and a strong delegation of power and responsibilities, especially at shop-floor level. The basic idea to include this element is that this can enable the possibility to react responsively and quickly to a problem
- Reduced division of labour (derived from the previous element)
- Continuous, product-oriented up-skilling of people at work. The need to get involved in the planning, programming and control of production process

[20] Published in 9 December 1989.

implies a continued training activity and development of the task competences.

- Product-oriented integration within the broader production processes.

As previously mentioned, an anthropocentric production system can be defined as a coherent set of technological and organizational innovations to improve productivity, quality and flexibility. "The production system that fits this condition is a computer-aided production system strongly based on skilled work and human decision-making combined with leading edge technology. It can be called an anthropocentric production system" (Lehner, 1992). In other words, "the strategic goal of anthropocentric shaping of system is to draw man out of his role as a plaything/object of the process and create the prerequisites enabling man to become the subject of production. This means the quality of production work: a) must be qualified and qualifying; b) should raise the level of autonomy of the work/worker and; c) must raise the degree of self-determination of the subject in production. These relatively abstract *characteristics*, however, arose in opposition to Taylorist or technocentric approaches (i.e. mechanistic ones where the production process is seen within the metaphor of the machine with man as a potential disruptive factor and part of the machine) (Rauner and Ruth, 1991, p. 18). Such production systems include normally robotic elements, and research on robotics has been strongly supported by companies and by state institutions for RTD support. That is why such approach deserved (and still deserves) a large attention from the scientific community as from the financial supporters to such research field. But the demands are essentially inter-disciplinary, and not only technological.

With such intentions some focused research institutes develop their activities and research agenda into these topics. An example comes from the US where the Robotics Institute at Carnegie Mellon University is one example. It is the only research institute where it was focused a field on the Anthropocentric Robotics. In that Institute it was agreed the importance of understanding people in order to build better robots. These robots were mostly developed as autonomous systems, and applied to the space research and development. In US some of the most advanced research on user-centred and autonomous systems is done on that sector (space) [21]. In Europe the ESA has been not dealing with such topics. Only the early ESPRIT projects on CIM (Computer Integrated Manufacturing) were during several years the main milestones for such strategies.

Such robotic development can be applied to industrial and human sites, like those where the working conditions are difficult (mining, nuclear power plants, underwater activities). The goals of that project on anthropocentric robotics were to develop a

[21] Already in 1987 the US National Research Council and NASA held a Symposium on "Human Factors in Automated and Robotic Space Systems".

"cognitive model" of how people understand robots, to integrate knowledge about this model into robotic systems, and to evaluate the effectiveness of this integration in improving human-robot interactions. Some studies of human-robot systems were developed under this research programme. One was the study of employees at NASA Ames and their involvement in the Mars Exploration Rover (MER) mission [22]. Another is a study of the interactions among scientists, roboticists, and a semi-autonomous rover as part of the Life in the Atacama project. From their perspective, robots that work with and for people must be designed not just to adapt to the physical world (the primary emphasis in traditional robotics) but also within the social world [23].

Toward this end, the work in this project has a distinct interdisciplinary character in its blend of the disciplines of design, social psychology, and robotics. This has been one of the most important projects designed in US under the anthropocentric robotics approach. In Europe, the above mentioned project SME Robot uses a similar principle. The approach on the development of specific robotic system for SME (small and medium-sized enterprises) usage has a different content than those that stress mostly the person-machine interfaces

The further development of programming environments is moving continually between the reduction of complexity of increasingly voluminous programs by means of abstract types of data and the increase of the degree of abstraction, which makes the reflection of one's own actions increasingly more difficult. The programming environments are not dealing with a sequence of subsequent steps anymore. All of programming procedures are just in use in more conventional automotive manufacturing companies, although the machine languages and increasingly also the assembler languages are retreating into a few niches. The development with the more important consequences in this area is currently being experienced by the group of professionals in the shape of the establishment of object-oriented programming languages and environments. Not all of them are engineers or computer technicians, but are also skilled operators. Beside a level of abstraction increased yet again, they require a radical "new thinking", that is no longer oriented toward data flows and processes (as in traditional procedural planning) but toward objects and the exchanges between these.

Also in recent years the demand for new and more natural human-machine interfaces has been increasing, and the field of robotics has followed this trend. The speech recognition is seen as one of the most promising interfaces between humans and machines, because it is probably the most natural and intuitive way of communication between humans. For this reason, and given the high demand for

[22] This study was already completed.
[23] In this same institute another project on People and Robots has been taken and developed in the recent years (http://www.peopleandrobots.org/). It is a group of researchers who are studying how people interact with robots.

more natural and intuitive interfaces, the automatic speech recognition (ASR) systems had a great development in the last years. Today, these systems allow, for example, the control of industrial robots in an industrial environment (in the presence of surrounding noise).

Another development is based on the adoption of high-level programming (HLP) techniques can overcome the drawbacks of classical approaches to programming. This can be important to understand how far research in this field is facing challenges and new steps. These types of programming techniques are crucial for the use of industrial robots (and for robot programming in general) since it could help users in the programming tasks, making them easier, especially when they must be applied to robots. The basic idea with HLP systems is to have humans teaching a task solution to a robot using a human-like procedure, which can be done in several ways and at several different levels as already mentioned. This is particularly important in manufacturing environments. And even more important when skilled operators are dealing with robots programming and control and integrated into semi-autonomous working groups in flexible manufacturing systems (FMS) with robots, or simply in robot cells.

The strategic research agenda for robotics presents also aspects related to societal issues. For example, it considers that a more widespread use of robots may lead to further labour displacement and an extension of the digital divide. This may lead to the exclusion of parts of the society from the benefits of advanced robotics. This may seem somehow simplistic once many studies confirmed the non-"technological determinism" and underlined the fact that labour displacement depends on the organizational options and not on the features of the technology itself. On the other hand, and still according to that European research agenda, job profiles can improve as robots take over dangerous, dull and dirty jobs not only in the manufacturing industries. Finally, enhancing the human body through robotics has both positive and negative implications for the able-bodied and disabled. This can be a more recent topic of debate and is presented in several chapters of this book (…) as well in a wide range of studies (Lebedev & Nicolelis 2006; Grunwald, 2007; Coenen et al. 2009).

However, more recently, the debate has been developed also over new issues that relate the working perception with autonomous systems (e.g. autonomous robotics). The cognitive task automation, even with visual programming or other user friendly tasks, may lead to over trust, complacency and loss of the necessary work environment situation awareness. This is a major constraint in complex work organizations teamwork, either in service or in manufacturing industries. That can end up into an operational gap, between system developments and its understanding and usability, by operators.

Today one can understand the wider use of the anthropocentrism concept applied to the production architectures, emerging a new value of the intuitive capacities and human knowledge in the optimization and flexibilisation of the manufacturing processes. This includes also the new risk situations that occur with the use of robotic systems. That implies a need to take into consideration qualitative variables in the definition and design of robotic systems, jobs and production systems.

With the development of European research activities (projects, networks, platforms) in the sequence of Framework Programmes of R&D the aims, methodologies, concepts and results changed. If in earlier stages the focus was on the organizational design and on the improvement of working conditions, later the main research focus laid on the software design and integration of new computer science concepts (agents, distribution, object-oriented programming). In the recent years new projects were still based on the development of industrial robotics systems integrating new achievement issued from other related fields of research (service, simulation).

In the manufacturing environment, robotic systems have been used in a wider type of workplaces and it seems that there is 'no general turning away from Taylorism' with all of these experiences on work organization and with alternative organization of automated systems. Indeed, after a period of widespread use of 'lean production concepts' in the early 1990s, the 'pendulum is currently swinging in the opposite direction' whereby many companies are reintroducing more Tayloristic work concepts. The developments of work organisation are very different depending on the specific national, branch (the Scandinavian or the German automotive models, are just examples) and company circumstances and particular market conditions.

The European experiences related to anthropocentric production systems based on the use of skilled workers and flexible technologies adapted to decentralised and participative organisational forms were forgotten and displaced by the so-called "lean production" movement. That anthropocentric production model responds efficiently to the new market demands, but mainly, allows a substantial improvement of the quality of working life (cf. Moniz & Kovács 2000). In fact, the first half of the 90's was strongly influenced by re-engineering (BPR): "to manufacture more and better with less" was the main objective. The rationalisation of operational processes, through the maximum grouping of jobs and tasks, the vertical compression and de-centralisation of decision for an increased flexibilisation, the suppression of wastes, there are the American alternatives to the Japanese challenge. Although a substantial part of re-engineering experiences was not well succeeded, those ideas continued to be largely disseminated (cf. Hammer & Champy 1993).

One obvious point that too often gets neglected is that competitive success based on quality and up-skilling is only one of a number of strategies available to organisations. Others include seeking protected or monopoly markets, growth through take-over and joint venture, shifting operations overseas, cost cutting and the new forms of Taylorism. And all of these have been also achieved with the integration of industrial robotic systems or other integrated automation complexes. Thus, a single trend is not clear.

Once again Rauner and Ruth underline that "a holistic approach to the design of technology and work must involve the consideration of human-centred technical and social criteria from the beginning of the design process. Amongst most contemporary engineering designers, the design of technology [24] and work is still viewed almost solely as a technical concern and it is therefore important that some method whereby human-centred considerations can re-shape this process is made available to designers in order to direct this trend towards anthropocentric principles" (Rauner & Ruth 1991: pp. 20–21). The strong weight of this technology-centred approach is still prevailing in the second decade of the 21st century, against all odds.

Technical systems without humans or anthropocentric-based systems? Some conclusion remarks

The actual state of the debate on can be defined when one analyses these projects and networks. In first place, it seems there is a need to relate the working perception with autonomous systems (e.g., autonomous robotics). Such relation did not appear in the decade of the 1990th or even sooner. This is a clear consideration when analyzing research on the new generation of robotic systems in manufacturing. And, second, in the recent years it became also clearer that the cognitive task automation may lead to over trust on technology and technological issues. Although there is a visible need There are very few research projects on social and political issues of anthropocentric strategies in manufacturing. It seems that this can lead to a new problem. The relation between risk, trust and technology development is becoming a clear topic where there is a shortage of studies. As described aboveFthe increase automation tools can lead to an increased complacency and loss of the necessary work situation awareness in highly automated environments.

This trend to over trust autonomous technologies can represent a major constraint in complex work organizations teamwork, where those technologies are applied, ending up into an operational gap, between system developments and its understanding and usability, by operators. In this way, many concepts issued from the work organization analysis, are connected with other concepts such as motivation, alienation, satisfaction, productivity, innovation, flexibility and business processes, learning organizations, networks and virtual enterprises. But these are not tackled by the robotics research. This should be understood as a topic to be researched more in the next future.

[24] Including autonomous robotics and systems [ABM].

In a recent meeting of the EUROP and EURON technology platforms, one official presentation mentioned the "Societal Challenges" of robotics as related to: a) Ageing Society; b) the Climate Change; c) Sustainable Manufacturing, and d) Safety & Security. At the same time, is said that European robotics has much to offer to tackle societal challenge, not only to create awareness, but also through that to improve marketing for robotics. In other words, the robotics technology community, including the equipment manufacturers, understood that the research (and through that, the knowledge) on social dimensions of autonomous systems will also contribute to their marketing aims.

Still connected with those above mentioned dimensions, it is known that 1/4 of European citizens will older than 65 years by early next decade, and twice as many older than 80 years than today (2010). Beside this "ageing society" effect, the climate change will introduce new environmental problems that will affect human health and living conditions. The awareness for a more sustainable manufacturing system is pushing the industry towards new behaviours towards ethics and towards the design of their products and services. Just very few cases can be mentioned [25], but the interest on the need to develop further knowledge of societal issues seems to grow. Slowly, because the counterpart in terms of major support to research on social sciences about these topics in Europe, Japan and US is not yet enough. This means that new specialized areas of robotics (beside Industrial Robotics) are emerging in close relation with new social needs, as the Professional Service Robotics, the Domestic Service Robotics and the Security & Space Robotics. This means that the growing perception of importance of social, political and ethical aspects is revealing also new market niches (that can be of some importance to manufacturers and to innovation support institutions) and new areas for technology development on robotics. At the same time, the development of robotics has contributed to a reduction in the energy consumption in manufacturing processes. This happens because research could develop lighter robots (with new material, and with improved technologies), and also could improve the energy efficiency of robotics. That contributed to improved energy efficiency of manufacturing process due to use of robots, with clear effects in terms of cost reduction. Another implication related with environmental issues, is the possibility that robotics can achieve to reduce material consumption, with less deficient products and efficient use of material (for example, with the painting robots) or low waste production. The previous experiences with anthropocentric systems demonstrated that this implication can be optimized when the development of robots and integrated systems is done together with the involvement and participation of their operators in the shop floor.

Where are the main fields where robotics is still supposed to develop in the next decade? In the recent EUROP meeting they were pointed out:

[25] For example, those that were already mentioned when it was referred the case of the European SME Robot initiative in the 6th Framework Programme. Some few more that had experienced the implementation of anthropocentric production systems.

- Large Structure Manufacturing (incl. civil eng., and at aerospace and shipbuilding)
- Robot with Integrated Process Control (self-programming and optimized cycle times)
- Rapidly Adaptable Manufacturing Cell for multi-robots systems
- Coordinated Mobile Manipulator (ceiling mounted robots, wireless control, loop-arrangements)
- Human-like Assembly Robot (flexible two-arm assembly, anthropomorphism)
- Robot Automation for Small-Scale Manufacturing (new robot systems for SME)
- Postproduction Automation (recycling, remanufacturing), with sensor development and for maintenance in under water, dangerous situations, small spaces
- Micro-Manufacturing Robot (for assembling and handling micro-components in multi-stage production lines)
- Robot Assistant in Industrial Environments (maintenance robot, forestry and agriculture robot, de-mining robot, professional cleaning robot, orbital and planetary robot agent and assistant, care robot, surgical robot, rehabilitation robot, logistics robots

Most (if not all) of these fields that need further research have inherent evidence of social and economical impact, and seem to be needed in the near future. Some of these are normally classified as “service robots”, and they will probably know an increase of their “population” of (intelligent) machines for the next years. Some of these service robots will be integrated also in the manufacturing sector, as the ones related to maintenance, logistics, inspection and quality control.

The robotic application to under water environment and to detection of fires and catastrophes will be used as fast they can contribute to cost reduction in such operations and have economical evidence of their utility. Here the need for an easy operability and accurate capacity will always be based on human competences, and their development can be only made on the basis of direct collaboration and participation of operators and users.

Health dimensions will be of further interest in the robotics R&D policies. Not only the surgical robots, but also the care giving and rehabilitation robots, and all related to provide missing body elements to handicapped people (legs, hands, arms). This field is perhaps the one where the ethical issues are becoming more decisive to define the bias of technology development. It is possible to experiment highly advanced systems and bionic equipment, but research will encompass the market needs. And these needs are defined by health policies and socio-economical strategies. Either defined by national and regional governments, or by large companies, it remains a governance issue.

The capacities of 'human' intuition and 'human' knowledge must be still a condition for the development of autonomous systems and also conditions for the optimization and flexibilization of manufacturing processes. That would mean alternative options at the organizational level. But, these new organizational qualities associated to the importance of human and social aspects of automation, also include new risk situations that can occur with the wider application of robotic systems.

It is possible that is emerging a new value of the intuitive capacities and human knowledge in the optimization and flexibilization of the manufacturing processes. This would be a pre-condition to understand the human-robot communication needs. If not, there are new risk situations that occur with the use of robotic systems. Finally, for such reason, there is a need to take into consideration qualitative variables in the definition and design of robotic systems, jobs and production systems. Serious research on robotic systems should imply also these issues in order to create good working conditions in future manufacturing.

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